ESR Processing of a New HighPressureDieCasting Steel

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Summary

Schmiedewerke Gröditz (SWG) is among the global players of special re-melted steel alloys production. Within the RFCS project nº 751360 HPDCSTEEL (High Pressure Die Casting Steel) a new ESR steel grade has been developed. At SWG the steel grade was produced using an open ESR unit. During re-melting the master alloy has been continuously added into the liquid slag bath and a modified ESR ingot of 20t has been manufactured. The ESR process was modified to increase the quality and performance of the steel, maintaining a constant distribution of synthetic carbides into the obtained ingot. A master alloy was placed on the bottom of the ESR machine before starting with the pre-charge. Furthermore, during re-melting the master alloy has been fed continuously using an installed balance system. No problems in the steel processing were detected, with a standard ESR melting and permanent feeding of the new alloy. The chemical composition of the alloy and of the liquid ESR slag was measured several times during the re-melting process, to determine if the master alloy was correctly dissolved in the melt.

Key Words

ESR, special steelmaking, re-melting, SHS alloy, hot tool steel, high pressure die casting, RFCS

Introduction

The present work shows the production of new high-pressure die casting steel at industrial scale. A new material's feeding approach has been set to gain full alloying capability at ESR unit.

The aim of the work is, that SHS (self-propagating high-temperature synthesis) master alloy is fed at re-melting to obtain synthetic Fe(Ti,Mo)-carbides in steel matrix. 1.2343 H11 hot tool steel has been chosen to be improved by synthetic carbide formation during re-melting and solidification.

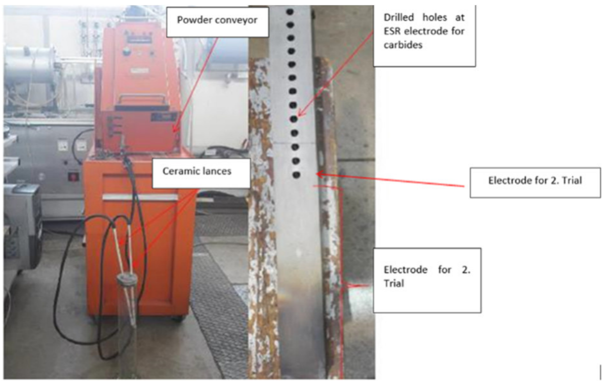

Figure 1: Design of experiments on laboratory scale

Study of dissolution of master alloy in steel and slag

It has been necessary to perform specific tests to identify and test the addition strategies in the ESR process of master alloy containing synthetic carbides to increase material performances. The tests have been performed at TU Bergakademie Freiberg (TU BAF) - Institute of Iron and Steel Technology in collaboration with SWG and TECNALIA.

Preliminary tests for estimating the dissolution behavior of master alloy in molten slag and steel have been performed. Master alloy has been positioned over steel and slag samples, studying the dissolution speed and distribution of synthetic carbides inside the steel and slag matrix using hot stage microscope. The dissolution into steel and slag has been proven within the experiments.

Different methods to evaluate the processing at laboratory ESR of the master alloy have been studied, Figure 1:

a) Insufflating the milled and grinded master alloy through ceramic lances during the ESR process.

b) Drilling and filling the electrodes with milled and grinded master alloy.

In total three mini ESR ingots have been produced on laboratory scale using ESR unit and feeding technique of SHS alloy at TU BAF, Figure 2.

Figure 2: Design of experiments on laboratory scale

A spectrometric analysis has been performed over the obtained different test bars. It is observed that in all three cases the initial concentration of carbon, molybdenum, titanium in steel matrix of ESR ingot has been changed, Table 1.

Element	Initial, %	ESR bar 1, Δ%	ESR bar 2, Δ%	ESR bar 3, Δ%
C	0.377	0.074	0.072	0.020
Mo	1.293	0.070	0.077	0.024
Ti	0.004	0.258	0.222	0.112

Table 1: Composition change of steel bars after re-melting using mini ESR

The main conclusion of the pre-study of dissolution of master alloy in steel and slag are:

a) Carbide enrichment possible by both methods (drilled electrodes with SHS master alloy or lance feeding system using SHS powder).

b) Equal distribution of carbides over the cross-section.

c) Carbides mainly at the grain boundaries.

e) Strong process parameter modification.

f) Deterioration of the block surface.

Industrial re-melting of the new steel

The ESR process was modified to increase the quality and performance of the steel, maintaining a constant distribution of synthetic carbides into the obtained ingot. 4 kg of master alloy was placed on the bottom of the ESR machine before starting with the re-melting of 1.2343 electrodes (Figure 3). A specific feeder was implemented to feed the master alloy into the ESR furnace at a constant feeding rate of 30 g/min.

Figure 3: ESR starter plate

The pre-casted 1.2343 electrodes were introduced into the ESR stand. A complete ESR melting was performed, Figure 4.

Figure 4: ESR ingot with reinforced steel matrix

As the master alloy is manufactured by a SHS process without an inert atmosphere shielding, part of the produced TiO2 can be dissolved directly from the master alloy (Figure 5). Another possibility could be that some titanium is not transformed into a carbide in the SHS reaction and remains as FeTi, where titanium reacts in molten steel with the oxygen presence in the open ESR reactor at SWG.

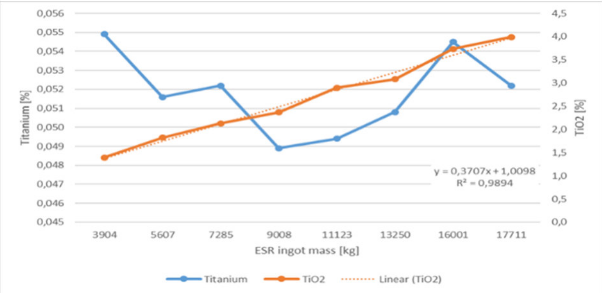

Figure 5: Mass% Ti, mass% TiO2 vs. ESR ingot mass

Via interfacial reaction at the melt bath/slag interface titanium is burned, producing TiO2. SWG ESR is an open ESR furnace covered with a dry air film on top of the liquid slag. That is why SWG uses deoxidizers such as Calcium-Aluminium to burn oxygen.

The industrial trial shows that molybdenum and carbon of the master alloy composition are dissolved in the steel alloy (Table 2). However, the titanium mass% increase in the alloy is only about 40 mass%. Most liley TiO2 formation hints a higher titanium yield in the final ESR steel composition.

Calculation of recovery of FeCTiMo master alloy	Ti, %	Mo, %	C, %
Ingot for ESR processing	0.0034	1.296	0.366
Obtained reinforced alloy	0.0522	1.330	0.394
Average Master alloy composition	54.0	11.0	12.0
Theoretical alloying in final alloy composition	0.129	1.322	0.419
Yield of alloying element from SHS	40.5	100.0	94.0

Table 2: Analysis of reinforced ingot after SHS master alloy feeding at ESR process

Conclusion

The present work can be summarized as follows:

1. 1.2343 ESR hot tool steel is reinforced using synthetic carbides of SHS master alloy,
2. SHS master alloy addition using lance feeding system during laboratory ESR is possible,
3. A stable re-melting on industrial scale has been achieved at SWG's ESR unit,
4. The forged ESR bar (Figure 6) on industrial scale shows homogeneous distribution of properties and an increase of final mechanical properties.

Figure 6: Forging 1020x280mm2 of reinforced 1.2343 ESR bar

Acknowledgments

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